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SOLAR IMPULSE AND E-FAN: TECHNOLOGY ADVANCES TOWARDS REDUCTION OF GREENHOUSE GAS EMISSSION IN AVIATION

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For many decades military forces around the world have continued their business without much concern about the environment and its degradation. The premise has apparently been that matters of national defence and security transcend environmental concerns. Of late, however, environment protection movements have been able to force governments to make their military forces conform to environment maintenance issues while the military forces continue with their essential tasks. The depletion of the ozone layer and widely accepted need to reduce production and use of ozone depleting substances was the first time that military forces were forced to incorporate environment concerns.[i] Today the need to reduce production of greenhouse gases is spurring new developments in the hither-fore untouched aviation sector.

Environment Concerns and the Military

By their very nature modern military forces require to operate on a routine basis with hazardous materials including explosives and inflammable material. The presence of such dangerous materials on board the capital equipment (main battle tanks (MBTs), Ships, Submarines and aircraft) of the three services leads to requirement for efficient fire fighting systems able to retard accidental fires and / or those caused by enemy action. Due to the limited space on board combat systems and the proximity of highly dangerous material carbon dioxide based fire extinguishers common in civil application proved

inadequate and more efficient extinguishers were developed. One such fire extinguishing system was based upon use of Freon gas.[ii] While Freon was effective in fire fighting, its other dangerous properties led to search for a better alternative which was developed in form of Halon gas.[iii] Over time Halon became a widely used fire retardant gas in use in various types of military equipment. Environment activists, however, pointed out that Halon is a very powerful ozone depleting substance and fought for a ban on the production and use of this gas.[iv] In order to accommodate the security forces' concerns the anti-Halon fight led to a ban on further production of the gas while allowing that existing stocks could be used, stored for future use, and even recycled from one weapon platform to another as long as no more Halon gas was being manufactured. As a result nations moved to create a system of "Halon banking" whereby they stored stockpiles of Halon gas for use in current and future weapon systems.[v] This concession was granted to provide time for environmentally safe alternatives to Halon to be developed. This was the first instance of the world's military forces being forced to toe the environment maintenance organisations' line. The global clamour about climate change and the perceived cause factors of this change in the climate including global warming (global warming is primarily attributed to production of

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greenhouse gases, such as carbon dioxide; the amount of emissions from a system is quantified as that system's 'carbon footprint'[vi]) leads to the reasonable assumption that in the years ahead even more pressure is likely to be brought to bear upon military forces to conform to a carbon neutral mode of operation.[vii] With the writing on the wall quite clear in this regard, it would be prudent for India's military forces and other essential sectors of the economy to proactively seek suitable solutions to issues that appear likely to dominate in the years ahead. Pre-planning and putting in place effective solutions well in time should help avoid a forced adoption of possibly sub-optimal solutions at a later date.

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Aviation and Emissions

Aviation, both military and civil was for quite some time safe from the climate change champions' clamour about greenhouse gases. Surface vehicles, especially those run on Diesel and Petrol, were in the firing line for their greenhouse gas emissions from the very start of the climate change debate.[viii] Pressure progressively built up on the vehicle manufacturing companies to improve efficiency in terms of mileage (the distance travelled per unit of fuel) and to reduce harmful emissions. This led to the introduction of catalytic converters in the exhaust system of vehicles and other innovations such as adoption of natural gas as a fuel as it was found that natural gas was a cleaner burning fuel than petroleum. Hybrid vehicles (in which a small petrol engine propels the vehicle in parallel with electric motor(s) thus reducing the exhaust emission from the engine as the electric motor shares the load.[ix] When the typical hybrid power plant powered vehicle is at cruising speed only the electric motors are used while the petrol engine also comes into use for the acceleration and heavy work, such as negotiating steep climbs, phases of the drive.) Hybrid vehicles demonstrated much reduced emissions per unit distance travelled.[x] Another technology was the use of purely electric power trains in vehicles. In these vehicles a

battery pack provides energy to electric motor(s) that propel the vehicle with nil emissions altogether. The carbon footprint of such purely electric vehicles comes from the power used to charge the battery pack. In case solar panels can be used to charge the battery pack the entire propulsion system can be carbon neutral.[xi]

The happy situation in which aviation was overlooked with regard to its carbon footprint came to an end when it was widely made known that the exhaust gases from jet powered aircraft were a major cause of ozone layer depletion[xii] and global warming.[xiii] This in turn led to efforts to curtail such emissions. In addition the carbon footprint of modern aircraft came to be a major issue. Aircraft and engine developers now devoted attention towards designing low carbon footprint machines. This effort included efforts to modify engines to give lower emissions while in parallel the aircraft airframe was to be made lighter and more efficient aerodynamically to reduce the energy needed to propel it through the air.[xiv] In fact new low carbon footprint aircraft became the latest attraction in the aviation field. In addition the then very high cost of aviation fuel gave a fillip to development and acceptability of these new efficient aircraft on purely commercial grounds. In order to cater to environmentalists' concerns as well as force adoption of the latest equipment some countries like the European Union nations imposed a carbon tax on airlines that flew non-low carbon footprint aircraft into their airspace.[xv] Such policies though opposed by other countries played a role in large sales of the Boeing 787 Dream liner, touted to be a very low carbon footprint airliner.[xvi] With this the writing on the wall is very clear. The push towards reducing the environmental impact of aviation equipment is likely to continue and gather more strength. Hence it is important to follow possible solutions that allow required tasks to be carried out while staying within the reduced carbon footprint boundary.

Solutions to Reduce Emissions in Aviation

Current technology fossil fuel burning power plants are limited in the low carbon gains that they can deliver through tweaking. Though application of advanced technology can reduce the carbon footprint, total elimination of harmful emissions is unlikely. As has

been the case with the automobile industry initial efforts to reduce carbon footprints are likely to lead to greater demands in future. This makes it important to examine technical solutions that have the potential to deliver greater benefits over a period of time.

The world's major aircraft manufacturers have devoted considerable effort at finding new carbon neutral and efficient means of propulsion for their aircraft. Some of the research has also been funded by national government agencies that see such futuristic technologies as important for their national security. The first attempts aimed at the fossil fuel used by in service jet engines. Replacement of the fossil fuel used with alternatives such as renewable biological source (plants and grains) derived fuels collectively called bio-fuels has been attempted.[xvii] The modification of fossil fuel guzzling jet engines to accept bio-fuels proved to be relatively easily solvable and tests were successfully conducted to prove that aircraft could operate safely with these bio-fuels in place of the traditional fossil fuels.[xviii] Bio fuels are somewhat cleaner burning than fossil fuels, but do not eliminate harmful emissions entirely.[xix] These bio-fuelled engines reduced need for fossil fuels but ran into problems of choice between growing food or fuel precursor plants.[xx] Also the exhaust gases from bio-fuel engines did not eliminate harmful components in the efflux entirely. The most promising alternative appears to be electrical power to propel aircraft.

The principles of the electric motor have been well understood for a long time. The breakthrough is in storing adequate electrical charge efficiently. This requires high capacity batteries that can retain the electrical charge efficiently till called upon to discharge at a controlled rate. These batteries could be charged through use of conventional electrical power from the power grid nor by means of solar cells integrated into the airframe of the aircraft. In either case such batteries would require to have high capacity as well as being very light in weight. Conventional lead acid batteries were ruled out early on and attention shifted to the more exotic Lithium ion batteries that are used widely in many consumer appliances. New research is poised to exploit the characteristics of nano scale carbon structures called buckytubes that show promise of an exponential leap in battery capacity increase and weight reduction.[xxi] High efficiency electric motors very similar to the motors

used in ceiling fans and other electrical devices can be manufactured with relatively little difficulty. This leaves power storage and battery size to be the only remaining stumbling block in widespread adoption of electrical propulsion in aviation. Solar powered aircraft have also been experimented with. While able to fly with no problems during daytime, such aircraft suffered from problems during night time with no solar radiation available to tap. Power storage or the "battery roadblock' thus confronted these machines also. Solutions were found through use of the then top of the line battery solutions in form of Lithium ion batteries. Through use of these experimental solar powered aircraft were able to demonstrate round the clock operation.[xxii] However, scaling up to commercial applications still requires better batteries and lighter construction.

Two relatively recent experiments bring hope of imminent breakthroughs in this field. The Solar Impulse solar powered aircraft flew across the USA mainland in day and night sorties between 03 May and 06 July 2013, to demonstrate the level of maturity already achieved.[xxiii] On 25 April 2014 Airbus is reported to have tested its electric fan powered aircraft successfully.[xxiv] Both these experimental craft are development experiments to develop technologies with commercial application. All these alternate energy applications in aviation currently cover propeller driven aircraft and not high speed jet engine equivalents. While propeller driven machines obtain higher efficiencies at lower altitudes and speeds they are unable to match the efficiencies and performance, especially speed, of turbojet or turbofan propelled aircraft. This drawback goes to show that while much progress has been made much more requires to be done to come to a stage where these new propulsion technologies can commence replacing legacy fossil fuel powered engines on aircraft.

The field appears wide open even today, the experiments by technologically advanced Western countries notwithstanding. Hybrid aircraft engines that use a small fossil fuel motor to supplement its electric power plants or / and to charge on-board batteries could be a practical way forward in the near term.

The problems in developing electric zero-emission power plants for aircraft in a way mirror the attempts to build electric powered cars. The progress made in developing and manufacturing practical electric cars such as the Toyota Prius, Tesla sedan, Chevrolet Volt, Nissan Leaf and the Indian Mahindra Maini Reva and E2O bodes well for the future of emission free aviation.

Especially in view of the fact that the field to develop environmentally safe aircraft is still wide open it behoves an aspiring nation like India to devote effort towards solving the twin problems of high density power storage and eking out higher performance from new propulsion technologies through a combination of advanced airframe design as well as better power transmission from batteries to the actual propulsion mechanism.

Conclusion

The global movement to save the environment has been gathering strength over the past few decades. While earlier the world's militaries and the aviation sector were overlooked by these "go green" movements, of late military forces all over the world have been included in the clamour for carbon neutral functioning. Aviation, both civil as well as military has also faced considerable criticism for its large carbon footprint. The efforts to sanction aviation through taxes and the like have given an impetus to development of alternate clean propulsion technologies. This has led to attempts to tweak current technology to increase efficiency of energy use while also seeking to develop viable technologies for the future. Electric propulsion is seen as the surest path towards a clean aviation industry, especially in view of the successful adoption of electric motors in land vehicles. As a country that aspired to rub shoulders with the best globally it behoves India to invest in researching these potential technologies to leap frog to the current and near future's cutting edge in aviation technology.

(Disclaimer: The views and opinions expressed in this article are those of the author and do not necessarily reflect the position of the Centre for Air Power Studies CAPS)

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